STUDY PROTOCOL:

IDENTIFICATION AND ASSESSMENT OF ENGINEERING CONTROLS FOR NOISE FROM POWER TOOLS USED IN THE CONSTRUCTION INDUSTRY

REPORT WRITTEN BY:
Charles S. Hayden II, M.S., P.E.
Rickie R. Davis, Ph.D.

REPORT DATE:
May 2003

REPORT NO.:
EPHB

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health
Division of Applied Research and Technology
Engineering and Physical Hazards Branch
4676 Columbia Parkway, C27
Cincinnati, Ohio 45226

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INTRODUCTION

The Engineering and Physical Hazards Branch (EPHB) has initiated this project to provide engineering noise control technology information for the prevention of noise-induced hearing loss (NIHL) among construction workers. In the hierarchy of control methods, engineering controls are preferred because the exposure is either removed or controlled at the source.

This study focuses its efforts on power tools used by workers at both commercial and residential construction sites. This study directly responds to the National Institute for Occupational Safety and Health (NIOSH) National Occupational Research Agenda (NORA) priority research areas in *hearing loss* and *control technology* to ". . . define further the causal contributions of these NIHL hazards . . ." and to ". . . identify, evaluate, and develop control strategies. . .," respectively.[1] Additionally, studying ways to reduce noise exposures to these construction workers addresses Healthy People 2010 Objective's to reduce new cases of NIHL and Occupational Safety and Health Administration's (OSHA) Unified Agenda to prevent hearing loss among construction workers.[2,3] This project also fosters working relationships with university researchers, the Laborer's Health and Safety Fund of North America (LHSFNA), construction worker's labor unions, power tool manufacturers, power tool distributors, and construction contractors.

STUDY OBJECTIVE

The objective of this project is to develop a noise control technology database consisting of power hand tools used in the construction industry with respective sound power levels (L_W) and workers' noise exposure (8-hour time-weighted average sound level [$L_{TWA(8)}$]). The database will provide information on identified noise controls and their effectiveness when applied to powered hand tools. Some examples of applied noise controls are listed in Appendix I. This database and specific noise control applications information will then be disseminated through practical guidelines, handbooks, and case study reports to aid safety and health professionals, noise control engineers, equipment and noise control systems manufacturers, and trade associations in applying effective noise control technologies. These materials will be made available to the public on a searchable web-site. The principal product of the study and the primary method of information dissemination will be the searchable web-site database of power tools used in the construction industry and respective operational specifications, L_W, and $L_{TWA(8)}$. These efforts will support the reduction of NIHL among construction workers by providing "buy quiet" and "designed quiet" information to power tool buyers and end users.

BACKGROUND

HEALTH EFFECTS

Approximately 10 million workers in the United States have permanent, irreversible hearing loss from noise or trauma.[4] Additionally, 30 million workers are estimated to be exposed to injurious levels of noise each day. NIHL is the most common occupational disease and the second most self-reported occupational illness or injury.[5]

Data indicate that people are losing hearing earlier in life and that men in the 35- to 60-year-old age group are most frequently affected.[6] NIHL can result from several kinds of exposure: (1) the traumatic, sudden one-time exposure to impulse noise, such as an explosion or gunfire, that can cause an individual immediate and permanent hearing loss; (2) the continuing exposure to high levels of sound from engines, electric motors, or woodworking equipment in the workplace or in recreational settings; (3) the long-term noise exposure causing subtle, progressive damage; or (4) the exacerbation of noise exposure effects due to individual vulnerability. NIHL is related to noise level, proximity to the harmful sound, time of exposure, and individual susceptibility. Many of these causes can be controlled by prevention.

The effect of NIHL may be an immediate hearing loss that is permanent and this loss may be accompanied by tinnitus, a ringing, buzzing, or roaring in the ears or head. Hearing loss and tinnitus may be experienced in one or both ears. Tinnitus may continue constantly or intermittently throughout a lifetime. The effects of hearing impairment also have serious consequences in the individual’s ability to communicate in social and family settings and to recognize auditory warnings, and it may lead to added job stress and decreased job performance.[7-9] Persons with NIHL are also more prone to workplace accidents as a consequence of their inability to hear audible warnings and they often have impaired speech perception.[7]

For the worker, hearing conservation involves, among other things, application of engineering controls to reduce noise emissions.[10,11] For the public, knowledge of potentially dangerous noise can be a significant factor in prevention of NIHL. One study showed that construction workers may work for four or five different employers in a single year, making it difficult, if not impossible, for employers to provide adequate health and safety training and medical surveillance.[8] Traditional interventions have been either unavailable or have proven to be ineffective for this mobile workforce. Additional factors that influence noise exposure among construction workers and complicate the collection of data, the development of controls, and the assessment of control effectiveness include the following: transient work-force patterns, temporary workplace(s), maintenance of equipment and tools, owned versus rented equipment and tools, and changing acoustical environments dependent on the alteration of structures as construction moves through different phases toward completion.

NIHL is common across most industries, but is the most prevalent occupational disease in the construction industry. Up to 50% of construction workers exhibit a hearing disability by age 50. Figure 1 shows the NIHL level of the typical carpenter vs. the typical non-noised exposed worker. A 1995 NIOSH health hazard evaluation (HHE) revealed that carpenters aged 25–35 years have the hearing equivalent of a 55-year-old worker who has not been exposed to excessive noise. By age 55, most carpenters need a hearing aid.[12] Figure 2 shows the noise levels of typical carpenters' tools and tasks.[13] Given these noise levels are in excess of the NIOSH recommended exposure limit (REL) of 85 A-weighted decibels (dBA) and OSHA's permissible exposure limit (PEL) of 90 dBA, it is little wonder the 55-year old carpenter suffers an occupationally related NIHL. Other studies have shown between 16% and 50% of all construction workers suffer significant NIHL.[14-17] Recent studies conducted at the University of Washington found that 40% of the noise exposure measurements made on carpenters and laborers were over the PEL established in the State of Washington—85 dBA for 8 hours.

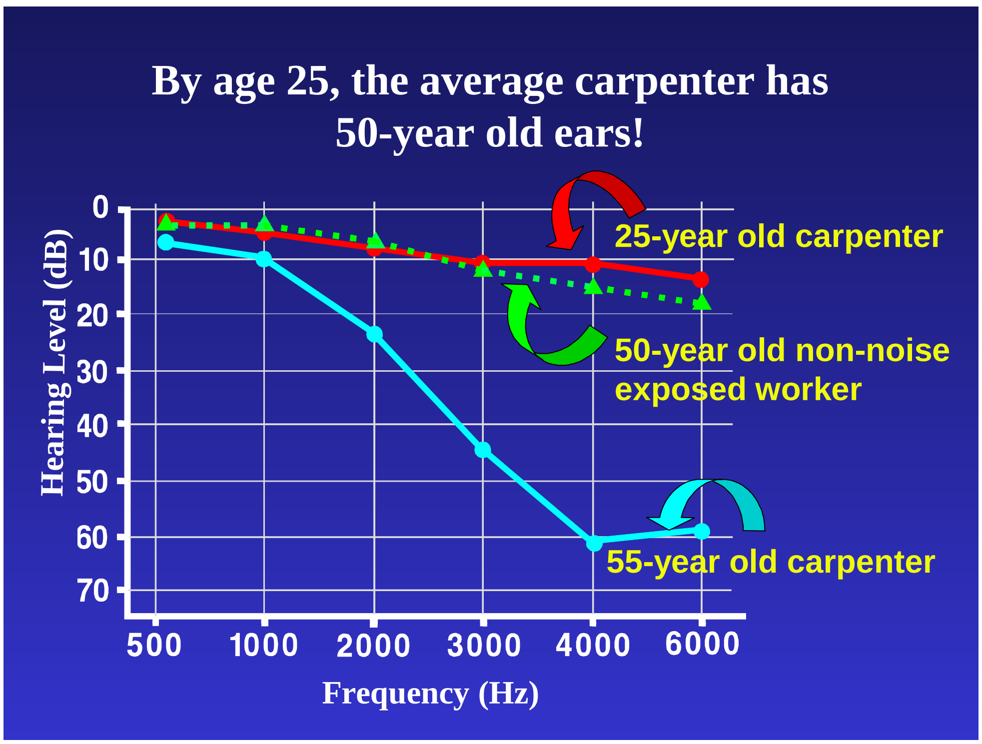

Figure 1 - NIHL level of the typical carpenter vs. the typical non-noise exposed worker.

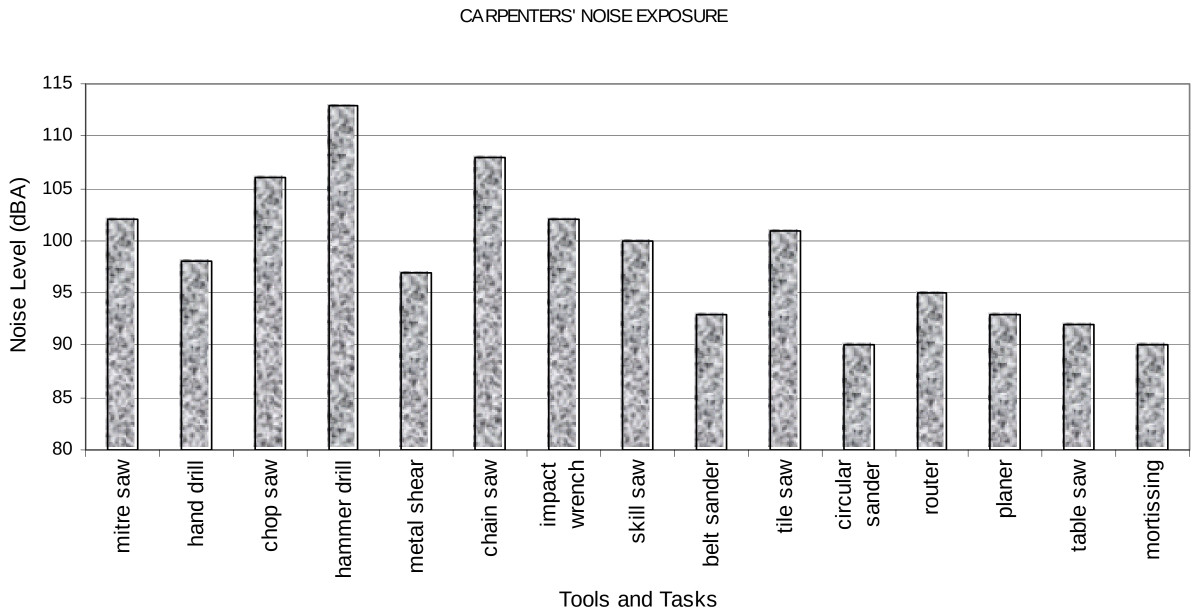

Figure 2 - Typical noise levels for various carpenters tools and tasks.[13]

Twenty-four percent of the measurements made on those who work in the so-called "quiet" trades, such as electricians, were also over this PEL. In addition, 50% of the construction workers at age 50, and 57% of carpenters employed for over 20 years suffered hearing impairment.

A number of studies have shown construction workers' general noise exposures from portable power tools range from 81 dBA to 113 dBA.[9, 18-21] Although, these previous studies focused on personal, task-based, and area noise level measurements, they did show that power tools were a major contributor to construction site noise. Figure 3 contrasts power-tool-use-intensive construction occupations—such as plumbers, ironworkers, carpenters, and electricians—which show higher rates of abnormal hearing, with occupations less dependent on power tools, such as painters or laborers.[22] Lastly, a linear relationship between a power tool's L_W and an operator's noise exposure ($L_{TWA(8)}$) has been shown, which, in turn, is related to NIHL situations.[19]

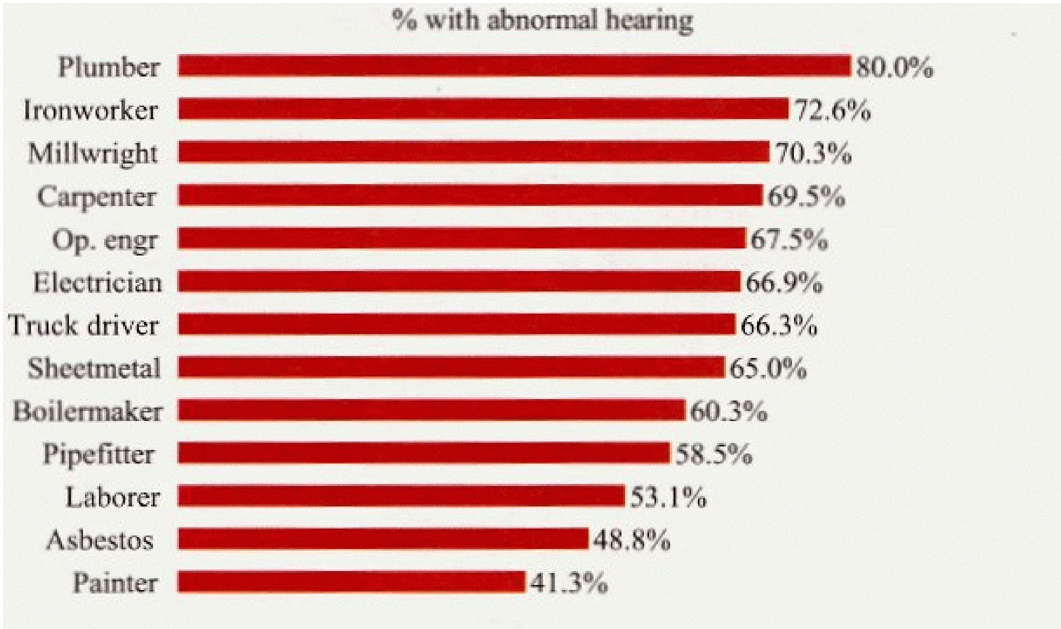

Figure 3 - Noise induced hearing loss, by trade, U.S. Department of Energy construction workers, 1997-2002.[20]

The costs associated with NIHL can be considerable. For example, more than 21% of all accepted Workers' Compensation claims for hearing loss in the State of Washington were filed by construction workers, who make up only 5% of the state's workforce.[23]

REGULATIONS AND POLICY

Regulation of noise exposure in the construction industry currently falls under OSHA 29 CFR 1926.52, Occupational Noise Exposure and OSHA 29 CFR 1926.101, Hearing Protection. These regulations do not have the stringent requirements promulgated for other industries (OSHA 29 CFR 1910.95, Protection Against Noise) to reduce noise exposure. For example, under 1910.95, employers are required to provide, maintain, and train employees in the use of hearing protectors while 1926.101 simply states ". . . ear protective devices shall be provided and worn . . . ." Further, 1910.95 provides guidance on noise monitoring, employee notification and accessibility to records, audiometric test requirements, record keeping, and employee training while 1926.52 provides no guidance at all on these issues. However, OSHA has recently released an advanced notice of proposed rule making (ANPR) aimed at preventing hearing loss among construction workers.[24] This ANPR addresses the deficiencies noted in the current 1926.52 document. While this proposed rulemaking may reduce noise emissions on construction sites, a final version of the rule has not been promulgated by OSHA.

The Office of Noise Abatement in the U.S. Environmental Protection Agency (EPA), which functioned between 1972 and 1982, made significant efforts to control noise in the general environment, including construction noise. While funding for the program was terminated in 1982 and the office closed, the statutory requirement, Noise Control Act of 1972, still stands.[25] These regulations are still in effect, but they are not being enforced. The Noise Control Act required EPA to regulate the labeling of products that emitted or reduced noise. A considerable amount of information about construction noise was generated by the agency, most of which is listed in EPA's *Bibliography of Noise Publications.*[26]

NIOSH advocates the primacy of engineering controls for controlling workplace exposure to noise. This policy states that, whenever feasible, engineering controls should be used to prevent workplace exposure to hazardous chemicals and physical agents, such as noise. Other less protective forms of control such as personal protective equipment (PPE), work practices, and administrative controls should be used only when engineering controls are not feasible.

EXPERIMENTAL DESIGN

STUDY POPULATION

In general, every power tool or small machine which produces hazardous levels of noise on a construction site may eventually be included in this study's database product. These tools and small machines number in the thousands. They will be acquired for study through purchases and tool loans from large tool users such as major construction companies.

Tools to be initially purchased for study by NIOSH are shown in Table 1. While not listed in any priority order, these selections are based on market research reports and Securities and Exchange Commission (SEC) filings to provide a broad picture of the power hand tool industry market share.[27, 28]

Manufacturer	Type	Model
Porter Cable	Belt sander	352VS
DeWalt	Box saw -miter 12"	DW705
Bosch	Core bits for block&brick-7" grinder	1752
Bosch	Grinder 4.5"	1347A
DeWalt	Grinder 4.5"	DW402
DeWalt	Grinder 4.5"	DW818
Bosch	Grinder-mini	1700A
DeWalt	Hammer—Demolition	D25900K
Bosch	Hammer—Demolition	11304
Bosch	Hammer—Rotary	11224VSR
DeWalt	Hammer—Rotary	DW531K
DeWalt	Hammer—Rotary smaller	DW567K
Bosch	Hammer drill	1194 VSR
Bosch	Hammer drill	11235 EVS
Hilti	Hammer drill	TE5
Hilti	Hammer drill	TE76
DeWalt	Impact wrench	DW290
Bosch	Jig saw	1587 VS
DeWalt	Jig saw	DW321K
Paslode	Nail gun—Finishing	IM250 II
Paslode	Nail gun—Framing	IMCT/325
Senco	Nail gun—Pneumatic	601 - framepro
Bosch	Router	1617EVS
Porter Cable	Saw—Chop	1410
Bosch	Saw—Circular	1655
Porter Cable	Saw—Circular	347K
DeWalt	Saw—Circular	DW364
DeWalt	Saw—Circular 8.5"	DW384
DeWalt	Saw—Reciprocating	DW309
DeWalt	Saw—Reciprocating	DW307
Porter Cable	Saw—Reciprocating	9737
DeWalt	Saw—Table 10"	DW744S
Porter Cable	Saw portable band	7724
Milwaukee	Sawzall	6527-21
DeWalt	Screw gun—Drywall	DW272
DeWalt	Screw gun—Drywall	DW272
DeWalt	Screw gun—Metal	DW268
Porter Cable	Vacuum cleaner	7812
DeWalt	Vacuum cleaner	DW792
Alto/Wap	Vacuum cleaner	SQ10
Porter Cable	Vacuum cleaner—Quiet	60113

Table 1 - Tool type and model to be included in both power hand tool database and in-depth study of noise emission characteristics and reduction.

Inquiries of power tool distributors and dealers of brands listed in Table 1 were made to gather information on models having the highest stock turnover or being bestsellers for that particular dealer.[29] The database population of power hand tools and machinery will depend, primarily, on this study's ability to gain access to specified tools and machinery.

Sound power (L_W) testing of power tools will be conducted in the hemi-anechoic chamber at University of Cincinnati, Cincinnati, OH. These data will become the focus of the power tools database. The chamber is located within the Structural Dynamics Research Laboratory at UC and is designated as the UC/NIOSH Acoustic Test Facility (NATF). The chamber dimensions will limit the tool size to a maximum of 1.0 meter by 1.0 meter by 1.0 meter volume. Power tools and equipment too large to be tested in the NATF hemi-anechoic chamber will be excluded from the database population.

DATA ACQUISITION

Acquisition of L_W measurements in the hemi-anechoic chamber will vary depending on the tool being tested. Some power tools, such as circular saws, will be tested in the prescribed full-speed, no-load operating condition, while other tools such as nail guns, will be tested in the prescribed loaded condition. Correction factors for background noise (K_1) and the test environment (K_2), as described below, will be applied to all L_W data. The L_W measurement of electric power tools will be accomplished in accordance with the American National Standards Institute (ANSI) 12.15-1992.[30] This standard prescribes the environment, instrumentation, operation, loading, device under test (DUT) setup, microphone locations, and data analysis of gathering L_W's of specified equipment. The standard also defines calibration, operation, and maintenance of all data acquisition hardware used for the L_W measurement. The standard operating procedure (SOP) in Appendix II details the ANSI 12.15 data acquisition process and the data handling procedure to be used in this study.

For example, ANSI 12.15 prescribes L_W data acquisition of circular saws be accomplished in the full-speed, no-load operating condition. Five LD Model 2541 microphones (Larsen-Davis, Provo, Utah) are located in the hemi-anechoic chamber as shown in Figure 4. The circular saw is held and operated as prescribed during the data acquisition process. Each of the five

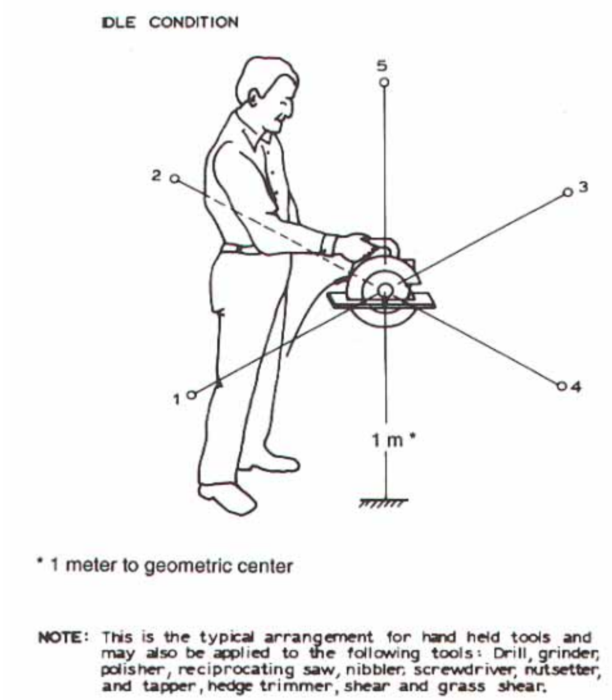

Figure 4—Circular saw test setup as prescribed in ANSI 12.15.

microphone signals feed to the LD 2226 12-channel multiplexor (MUX) as shown in Figure 5.

The MUX is cabled to the LD 2900B real-time analyzer (RTA). The RTA provides microphone power through the MUX and data acquisition control throughput from a desktop PC running CAPS software. The RTA sends 1/3 octave band sound pressure level (L_P) measurements from

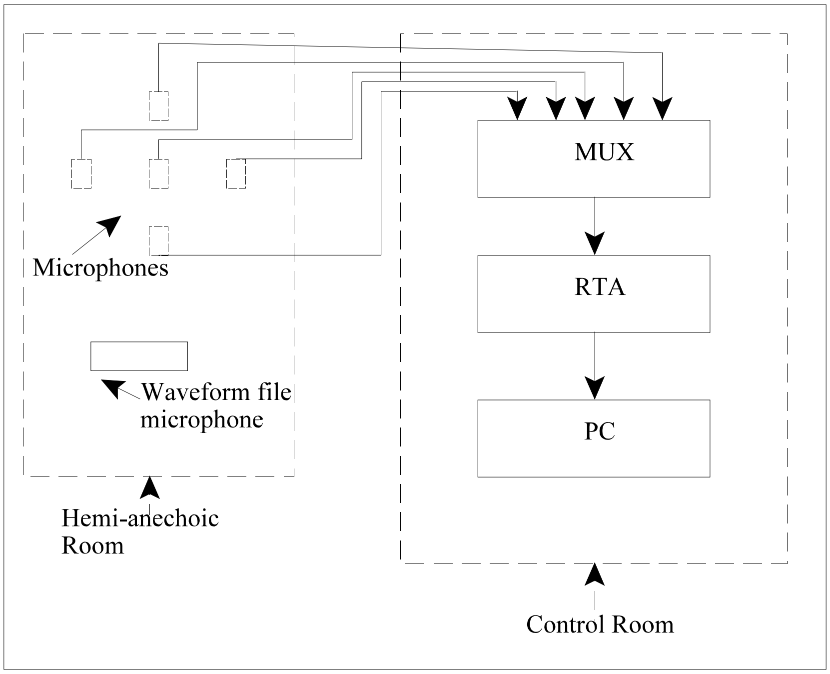

Figure 5 - L_W measurement acquisition setup.

each of the five microphones to the CAPS software for analysis. From the resulting L_P data, L_W is calculated using:[30-33]

$$L_W = \overline{L'_P} - K_1 - K_2 \qquad (1)$$

where,

correction factors for background noise (K_1) and the test environment (K_2) are applied to all L_W data and,

$$K_1 = -10LOG(1 - 10^{-0.1(\overline{L'_P} - \overline{L''_P})}) \qquad (2)$$

$$\overline{L'_P} = 10LOG(\frac{1}{N}\sum_{i=1}^{N} 10^{0.1L'_{Pi}}) \qquad (3)$$

$$\overline{L''_P} = 10LOG(\frac{1}{N}\sum_{i=1}^{N} 10^{0.1L''_{Pi}}) \qquad (4)$$

$$K_2 = L_W^* - L_{Wr} \tag{5}$$

and,

N is the number of microphones used (5 in the case of ANSI 12.15),

L_{pi}' is the individual microphone output from CAPS software while tool is being tested,

L_{Pi}" is the individual microphone output from CAPS software while only the background noise is measured (i.e., tool is not running),

L_W^* is the environmentally uncorrected sound power level of the RSS-400 (Campanella and Associates, Columbus, OH) reference sound source (RSS) as measured in accordance with the measurement method used (in this case, ANSI S12.15-1992 and ANSI S12.36-1990),[30,34] and

L_{wr} is the calibrated sound power level of the RSS, as provided by the RSS manufacturer.

Standards for L_W measurements may not exist for certain equipment and tools, or existing standards may be insufficient in their detail. In these cases, ISO 12001:1996E, “Noise Emitted by Machinery and Equipment—Rules for the Drafting and Presentation of a Noise Test Code” will be explored with recommendations for new standards development or revision of existing standards to be determined as project resources permit.

A waveform file of the tool being tested will also be collected during each L_W measurement test run using an LD Model 2541 microphone. This microphone will be positioned in the hemi-anechoic chamber at a location indicative of the hearing zone of a worker operating that particular tool. The waveform file will then be used to calculate a worker’s potential noise exposure. NIOSH Impulse Measurement System (NIMS) software, developed by NIOSH, will be used to analyze the wav file and calculate certain parameters, such as Leq, LeqA, 1/1 and 1/3 octave bands, and frequency spectrum. The waveform files will also be added to a library and made available to other researchers for further analysis (i.e., examination of impulse noise, discrete tones, or transient analysis). The $L_{TWA(8)}$ will be reported along with the L_W of the tool tested. The $L_{TWA(8)}$ will be calculated using:[35]

$$L_{TWA(8)} = LC + \frac{Q}{LOG(2)} LOG(\frac{D}{100}) \qquad (6)$$

$$D = (\sum_{i=1}^{n} \frac{C_i}{T_i})100 \qquad (7)$$

where,

n= number of discrete exposure measurements,

LC = Criterion Level - 85 dBA,

Q = Exchange Rate - 3 dB,

D = Noise Dose (%),

C_i = Actual Exposure Duration (hrs), and

T_i = Permissible Exposure Duration (hrs).

STATISTICAL ANALYSIS

Statistical analysis of the data requires establishing the mean and variance of the sound power level measurement through repetitive testing. The sample mean ($\overline{L_W}$) and sample variance (s^2) will be determined by:

$$\overline{L_W} = 10LOG(\frac{1}{M}\sum_{i=1}^{M} 10^{0.1L_{Wi}}) \qquad (8)$$

$$s^2 = 10LOG(\frac{1}{M-1}\sum_{i=1}^{M}(10^{L_{Wi}} - 10^{\overline{L_W}})^2) \qquad (9)$$

Where,

M = number of test runs (established per equation 10 below),

L_{Wi} = Sound power level test run result (equation 1).

After each test run, the power tool being tested will be removed from the hemi-anechoic chamber. Per International Organization for Standardization (ISO) 3744, after a short time interval (for example, to allow for the tool to return to room temperature), the test for that same tool can then be re-setup and the test repeated.[31] This $\overline{L_W}$ measurement test will be repeated M times until the 95% confidence interval of the standard error (SE) is ±1.5 dB or;

$$\overline{L_W} \pm t_{M;0.05} \frac{s}{\sqrt{M}} = \overline{L_W} \pm 1.5\, dB \textit{ with } 95\% \textit{ confidence.} \qquad (10)$$

where,

$t_{M;0.05}$ is the Student's t variable and

s is the standard deviation of repeatability.

NIOSH researchers anticipate $\overline{L_W}$ measurements taken in the hemi-anechoic chamber will provide;

$$s \leq \sigma_R \qquad (11)$$

Values of σ_R, the standard deviation of reproducibility, are shown in Table 2. The σ_R includes uncertainty associated with repeated measurements on the same noise source using the same measurement method at different times and under different conditions (different laboratory, different operator, different apparatus). Table 2 values are standard maximum values for establishing an engineering grade measurement.[36] As reported in ISO 3744 (page 2, note 7), ". . . if it is difficult to maintain stable operating or mounting conditions for a particular source (power tool), the standard deviation of repeatability may not be small compared with the values given in Table 2. In such cases, the fact that it was difficult to obtain repeatable sound power level data on the source should be recorded and stated in the test report...."[31]

Octave band center frequency (Hz)	**1/3 Octave band center frequency (Hz)**	**Maximum Standard deviation of the mean value, σ_R decibel (dB)**
125	100 to160	3
250	200 to 315	2
500 to 4,000	400 to 5,000	1.5
8,000	6,300 to 10,000	2.5
A-Weighted		1.5[(1)]
(1) - Applicable to a source that emits noise with a relatively "flat" spectrum in the frequency range 100 hertz (Hz) to 10,000 Hz.		

Table 2 - Estimated values of the standard deviations of reproducibility of sound power levels determined in accordance with ISO 3744.

The mean and variance for the $L_{TWA(8)}$ will be calculated similarly as shown in equations 8 and 9. As the mean sound power level and s^2 data with corresponding $L_{TWA(8)}$ are calculated from the lab measurements, the data will be placed into an intermediate database and published on the NIOSH intranet. A NIOSH in-house review procedure will be implemented to review these new data prior to placing them on the public accessible searchable internet web-site. The approved internet web-site database will be updated on a monthly basis from the more frequently updated intranet site. Prior to posting on the public internet web-site, notification and L_W data will be sent to the manufacturers of those respective power tools. NIOSH also plans to publish the internet web-site data in brochures and in research and trade journal articles.

DATABASE

The database product of this project will be used as an informational database to provide tool sound power levels to the public. The database will be accessible via the NIOSH web-site. The database will be developed in combination with other research studies examining construction tasks, phases, occupations, and types of construction. With this information, reasonable assumptions can be made as to the potential occupational noise exposure expected for various occupations, tasks, etc. using Task Based Exposure Assessment Model (T-BEAM) estimating techniques. The relational database for construction tools is being developed in Microsoft Access format. The database captures tool types, tool models, tool manufacturers, and decibel power level (Figure 6). The database is expandable to include new tools and new manufacturers

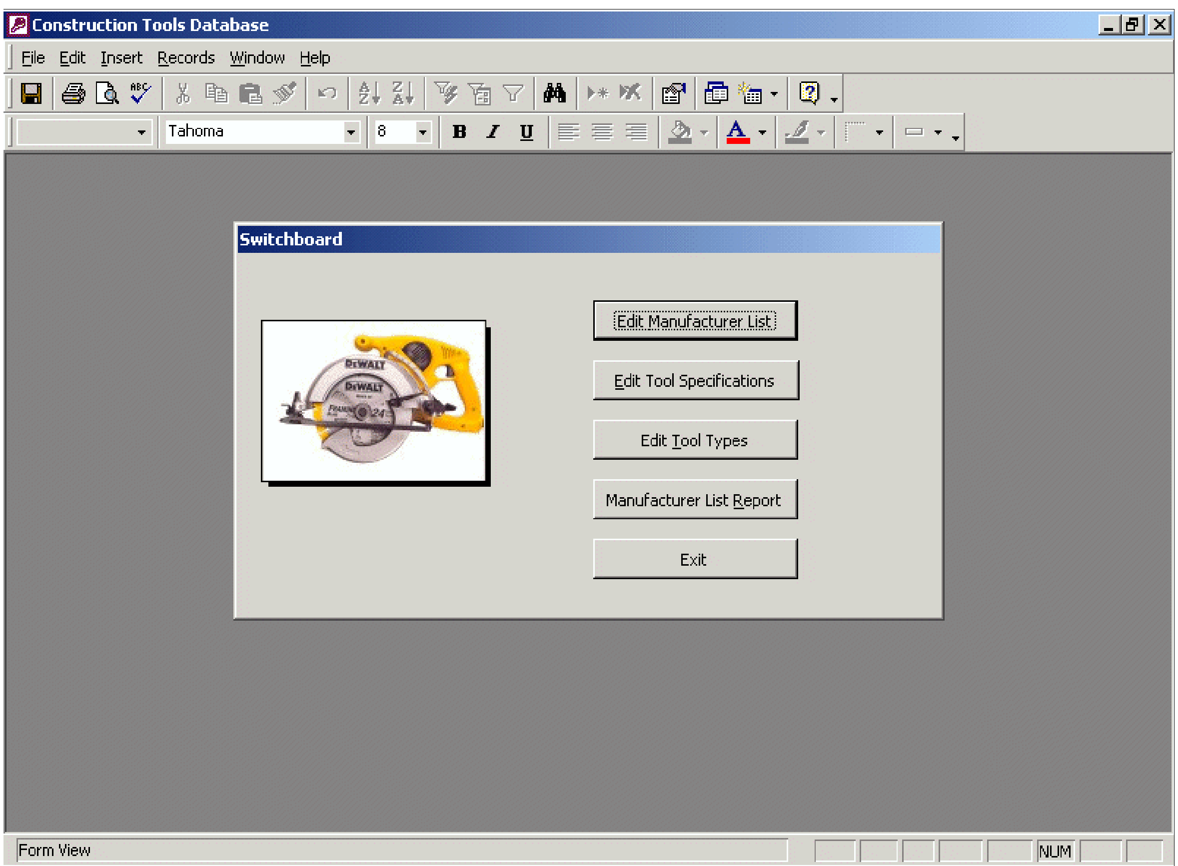

Figure 6 - Opening screen of the Construction Tool database allows for editing of the three data tables or automatic generation of a tool report by manufacturer.

as the power tool population changes over time. A report can be generated of all tools by each manufacturer or of all tool types by all manufacturers. Operational specifications in the database are derived from manufacturer web-site pages, published catalogs, and other tool web-sites.[37, 38] Figure 7 is an hypothetical page from the web-site that could be generated from information obtained from the database.

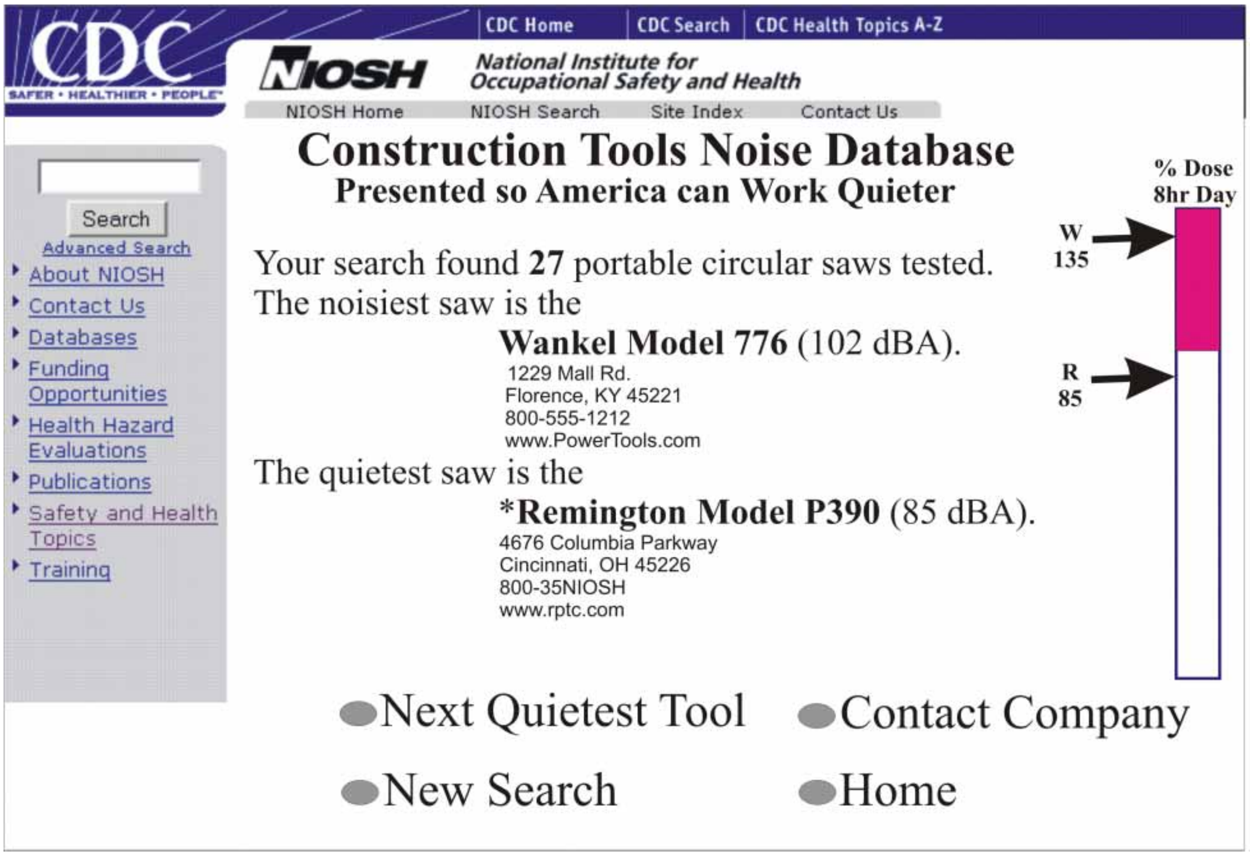

Figure 7 - Hypothetical web-site showing information obtained from the Construction Power Tools Noise Database. Current web technology allows for an interactive page on which the customer can set the criteria important for their needs.

The database, in combination with workers' noise exposure data, will be used by NIOSH researchers to drive future noise control research and to select power tools for an in-depth study of noise emission characteristics and control applications. These in-depth studies will be accomplished under individual protocols separate from this study protocol.

STUDY TIME LINE

The time line for this study is presented in Table 3. The project will be run through fiscal year 2005. During this time frame of project, the database will be developed and maintained with information disseminated on the web-site and in brochures, articles, presentations, and workshops.

Overall Project	FY2003			FY2004				FY2005			
	2nd qtr. JFM	3rd qtr. AMJ	4th qtr. JAS	1st qtr. OND	2nd qtr. JFM	3rd qtr. AMJ	4th qtr. JAS	1st qtr. OND	2nd qtr. JFM	3rd qtr. AMJ	4th qtr. JAS
Develop study protocol.	XX										
Internal Review		X									
External Review		X									
Submit for final approval		X									
Acquire and test a sample of power tools		XX									
Develop Web-site/Database Format		X	XX								
Populate and submit initial web-site database		X									
Publish web-site database			X								
Maintain database			XX	XX	XX	XX	XX	XX	XX	XX	XX
Document L_W's/ noise control technology.	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX	XX
Acquire and test other tools		X	XX	XX	XX	XX	XX	XX	XX	XX	XX
Manage web-site based information system		X	XX	XX	XX	XX	XX	XX	XX	XX	XX
Develop handbook on noise control of power tools			X	X	X	X	X	X	X	X	X
Publish Handbook.											X
Workshops/Conferences on construction noise control technology					X			X	X	X	X

Table 3 - Time line for project progress and completion.

FIELD ELEMENT

The controlled environment of the hemi-anechoic chamber will provide an accurate assessment of power-tool noise levels, noise control assessment, and definition of each tool's acoustic phenomena. Providing this lab-based assessment makes the database more fully comparable across the entire study population of power tools. Using this baseline data of power tool L_W's, it will be possible to determine the combined background noise effects, reverberant effects, temperature and humidity effects, operator effects, and tool condition effects on field measurements of worker' noise exposure taken using the same T-BEAM. Field evaluation of the tools is a natural extension of the noise level and control work. These field evaluations will focus solely on worker exposure measurements taken in accordance with ANSI 12.19.[35] The limitations of acoustical field evaluations can be properly overcome by comparing the laboratory and field data to develop correlations between previously unknown field factor's effects and precise noise level as measured in the lab. Field evaluations of noise emission from power tools already tested in the lab will be conducted periodically as permitted. NIOSH researchers will conduct these worker noise exposure measurements at local construction sites accessed through existing partners.

SAFETY

During this study, the procedures outlined in the Centers for Disease Control and Prevention, Health and Safety Manuals and the Division of Applied Research and Technology, Safety Manual will be followed.[39] Particular focus on specific manual sections will ensure the industry's use of personal protection equipment, provision of adequate illumination, maintenance of proper housekeeping, practice of fire prevention, proper storage of materials, and safe operation of power tools. All NIOSH research personnel will wear safety glasses, hard hats, safety shoes, respirators, coveralls, and hearing protection as needed. Power tool manufacturer's safety instructions will be reviewed prior to operating the respective tool for testing purposes. Additional safe practices for the operation of specific power tools are provided by the Power Tool Institute and will be followed as recommended on their web-site.[40]

REFERENCES

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APPENDIX I - Engineering Noise Control Examples

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INTRODUCTION

In many industries, the use of engineering noise controls is very low despite the fact that such controls are commonly available and despite the fact that workers in those industries continue to lose their hearing. By making precise, real-world noise control technology information available in a timely fashion, we raise the confidence level that investments in engineering noise control will, in fact, achieve the desired outcome. Through the assistance of partners within industry, labor, academia, and other government agencies, the study will identify and evaluate available engineering controls that reduce power hand-tool noise exposures to construction workers. These power hand-tool noise emission levels and application and effectiveness of noise controls will be provided to power tool designers, manufacturers, construction contractors and workers, general occupational safety and health professionals, and the engineering noise control community.

NOISE CONTROL TECHNOLOGIES/APPLICATIONS

Given that noise induced hearing loss (NIHL) among construction industry workers is higher than that in all other industries and the Occupational Safety and Health Administration and the Environmental Protection Agency have not been able to mandate a change in the construction worker's noise environment, it is paramount that other options be examined.   These options include motivating manufacturers of noisy powered hand-tools and equipment to apply new and existing noise control technologies to their products. This application must be shown to increase performance, decrease operating and manufacturing costs, or increase quality. This is often possible because power tool performance may not be optimized or may have significant inefficiencies. When these inefficiencies create noise, there is an opportunity to design or apply a noise control solution that *will be* implemented by the manufacturer of the powered hand-tool or equipment. Historically, the driving force behind noise control technology has been the automotive, aerospace, and more recently, the household appliance industries. Applied technology used in these industries is largely focused on reduction of vibration, barrier absorption of sound, and the improvement of sound quality. But, these new and existing technologies are not widely disseminated across industries (i.e., the powered hand-tool manufacturing industry), thus making it difficult for equipment designers, installers/assemblers, maintenance personnel, or operators to understand the efficacy and use of noise controls to achieve optimal operational efficiency through maximum noise reduction. Either proper application of noise controls in a limited environment (where the information is not widely disseminated) or inappropriate application of existing noise controls can diminish the overall effectiveness of current technology to reduce NIHL.

Various methods of controlling noise emissions on construction industry power hand-tools will be identified and reported secondarily to the power hand-tool database of L_W's. Some examples of these noise control technologies currently being researched or used on construction machinery, equipment, and power tools are overviewed below. While the examples below are not inclusive, they do provide a indication of where noise control technology is currently at and where the technology is heading in the near future.

Modeling

Use of hazard *exposure models* provides a cost effective exposure assessment tool, an appropriate exposure control plan opportunity when designing and implementing new equipment and power tools, and the models to assess the safety of products on the front end of the process ... before they are used on construction sites.[40] Further, integrating existing *computer-aided engineering product models* with specialized hazard exposure models can allow noise levels to be known at the equipment and power tool design stage and corrected in a time and cost-efficient manner.[41] These models could also be used to rank average exposure levels by task/job or combined with task based exposure assessment methods (TBEAM) to predict occupational noise exposure levels.[40]

Structural Vibration Control

Noise control technologies developed in the aerospace and automobiles industries to reduce vibrations and noise can be widely utilized in the design and manufacture of construction equipment and power tools.[42] The destabilizing effects of structural vibration transmission can be eliminated in the course of investigating noise source location and elimination.[43] This will lead to a higher quality, more durable product, that operates at greater efficiency.

Engineering noise control examples:

Piezoelectric sensors provide simple and economical feedback/control signals for real-time active control of vibration induced noise.[44] Even better, shunted piezoceramic materials (PZTs) have been shown to decrease sound transmission. These shunted PZTs are a simpler and more cost effective alternative to actively controlled PZTs. While constrained layer damping may provide sound transmission loss comparable to PZTs, it is at a substantially higher weight. PZTs have been shown to both reduce structure borne noise and increase transmission loss in structures.[45]

One study showed that increasing the stiffness of a belt tensioner or decreasing the thickness of a drive belt reduces the vibrational power flow into the tensioner.[46] Examining the power flow through a drive belt further may produce more durable, higher quality drive belt designs which operate quieter since vibration induced noise is minimized.

Induction motors are the primary force input into various electrically powered hand-tools and machinery. The structural excitation resulting from this force input and ensuing vibration induced noise should be examined to eliminate either the initial force input into the motor casing or support structure or prevent the flow of vibrational energy through the structure or ensure the structure is properly stiffened or damped to prevent the “firing off” of sound.[47] This characterization of a structure’s ability to transmit structure borne sound power can be advantageous to designers and manufacturers of construction equipment and power tools when product quality issues are related to vibration and noise phenomena.[48]

Numerically controlled tunable vibration absorbers show many advantages over current absorbers. These controlled absorbers provide greater amplitude reduction at low frequencies and require the use of fewer absorbers.[47] Other active controls include dither controls, which input a high frequency signal to a structure. Dither controls eliminate static friction squeal by keeping frictional surfaces slightly slipping at all times.[50] Other, less exotic but nonetheless effective, controls are rubber mount isolation techniques, used to minimize the power transmission through a structure.[51]

New vibration identification algorithms can be employed to detect "the coming of noise" through detection of the "coming of vibration" due to, among others, gear and bearing failure.[52] These sensitive diagnostic techniques can be used where previous techniques such as time signals are less likely to identify a problem until the failure is closer to being catastrophic.[53]

Fans

The addition of flanges to the blade tip and of fabric near the blade trailing edges of an axial flow fan can provide as much as 9 dB of noise reduction above 1 kHz.[54] A lesser noise reduction can be found using unevenly spaced fan blades, yet the sound quality improvement found by using this techniques was significant. This was due to providing a more broad band emission, thus elimination of an existing siren effect.[55]

Specific Applications

Pneumatic tool vibration and ensuing noise and hand-arm vibration can be reduced by employing the natural spring properties of air trapped in a cylinder.[55]

Properly sized mufflers should be used on the exhaust system of combustion powered construction equipment.[57] While most mufflers are subject to volume/weight constraints, the trade-off should not be at the expense of the muffler's effectiveness.

While only a small volume of research has been reported in controlling noise of power hand-tools, noise levels at the source can be significantly reduced by the simple redesign of the motor cooling fan blades, or the addition of damping material to reduce impact noise, or application of inexpensive barrier controls.[58,59] For instance, a reduction in circular saw blade noise by examining the tooth and air flow design can be easily demonstrated.[60,61]

Portable internal combustion generator noise emissions are reduced 8.5 dBA through a combination of enclosures, damping, and stiffening.[62]

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APPENDIX II - ANSI 12.15 Standard operating procedure

UC/NIOSH Acoustic Test Facility (NATF)

Test procedure flowchart for ANSI12.15/ISO3744/LDCAPS for sound power levels of power tools and equipment using Larson-Davis CAPS automated sound power software in the NIOSH 74 cubic meter Hemi-Anechoic Chamber in accordance with ISO 3744

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Revision Log

Revision 0; Date January 16, 2003
On *Date* this test procedure was revised. Changes to the procedure included:
List Revision ...

Receive Sample

Sample Delivered

DUT (Device Under Test) is delivered to NIOSH Acoustic Test Facility (NATF)

Complete Project Request Form

Complete a Project Request Form. This form contains fields for information that will be needed for the database record for this test. Include the Project Request Form in the test file.
Master copies of the NATF Project Request Form can be found in the UC-SDRL Acoustic Lab file system.

Enter Project into NATF Test Log

Enter the Project Request on the NATF Master Test Log, which is located at the beginning of the Laboratory Technical Handbook. Assign the test a sequential number in accordance with the test numbering logic defined in the Document Control Program that is located in the NATF Quality Manual, Section 1.

Assign a Test Date

If the test is not to proceed immediately, the Laboratory Technical Manager will assign a test date to the client.

Store DUT or Proceed with Test

Store DUT until the assigned test date or proceed with test if DUT is delivered on the date of the test.

Create Test File and Documentation

Create a Project File

Open a physical file for the test by creating a green hanging folder and manila folder with the test number on it. Place a copy of the Test File Document log in the file and enter the Project Request Form as the first document in the file. Keep all forms, data sheets and other documentation generated as a part of this test clipped into this file folder in reverse chronological order. See *Document Control*

Program (NATF Quality Manual, Section 1 – to be developed) for more information on how to number tests, where files are kept and how to log items into your file.

Create Database Record

Create a test file in the database and enter the information from the Project Request Form into the database.

Measure Environmental Conditions

As environmental conditions are required fields in the database, environmental conditions in the test chamber should be measured at this time. See "**Measuring Environmental Conditions**", Measuring Temperature and Relative Humidity, for procedures on how to measure and record environmental conditions.

Set Up Test

Power Up Lab Bench, Test Equipment and Computer System

Power up the equipment on the lab bench by turning on the power bar. For ISO 3744 Sound Power tests using the Larson Davis CAPS (LDCAPS) software, the Larson Davis 2900B Analyzer and the computer system labeled "Larson-Davis 2900B Control Unit" must be powered up.

Check Microphone Array Setup

The microphone array is typically left set up in the hemi-anechoic chamber. If the array is not set up, see "Setting Up the Microphone Array" in Appendix 1. If the microphone array is already set up, check that all mics are in the proper position by looking at the position of each microphone in the chamber. Each microphone should be directly above the dot on the floor and at the elevation noted on the dot. Reposition any microphones that are out of position.

Bring DUT into Chamber

Bring the DUT into the chamber and set it on the floor, in the center of the chamber. The center of the DUT should be directly over the 0,0 coordinate in the center of the test chamber. See Appendix X for more information on how to position specific types of equipment.

Load the CAPS Software

Boot Up theLarson-Davis 2900 control computer. After the computer has booted into Window, double click the CAPS icon located on the desktop to start the Larson-Davis CAPS Program (LDCAPS).

The LDCAPS program should come up with a window labeled "Untitled-CAPS.

Start Automated Test Process

To start a test, click on the green flag icon on the LDCAPS tool bar (second icon from left).

The LDCAPS program will prompt the user, indicating that any unsaved test data in memory will be lost. If you are starting this test from scratch, click on “Yes”. If you are starting a new test after having completed a previous test, be sure your test data has been saved before selecting “Yes”.

The LDCAPS program will prompt the user to connect the LDCAPS software to the analyzer. Clicking on “OK” will bring the user to a Connection window with several communications setup parameters. See **Setting up the Larson-Davis CAPS Software** for information on the default values for communication parameters if the pre-selected values do not allow you to connect to the analyzer.

Click on Connect to make the connection.

Load the Default Measurement File

The software will prompt the user to open a CAPS Test File. It will ask if you wish to “Create a New Test” or “Load an Existing Test”. Click on “Load an Existing Test”.

The default test file template is named 00_000_x and is located in the C:\NIOSHUC directory. Use this file if this is the first test during this measurement session. Highlight this file and click Open to retrieve it. If this is not the first test of this measurement session, and you wish to share the calibration and ambient noise data from a previous test, then open the file that was created during the previous test and edit the source and/or operation conditions as required.

Note : It is acceptable to share ambient noise and calibration data that were collected during a measurement session. A measurement session is defined as a series of consecutive measurements, conducted without powering down the instrumentation system, not to exceed one day. Ambient noise data should only be shared if the DUT sound power is sufficient that the bands which control the Awtd sound power are significantly above the ambient noise level in the chamber and there has been no change in ambient conditions (i.e. AC systems came on). If any question arises concerning the validity of ambient noise or calibration data, then data shall not be shared.

The program will prompt the user that the Test has been Loaded and ask if you would like to edit any of its’ information? Click on Yes.

To verify that the default test file template is configured with the proper default settings, see Configuring the Default Measurement File in **Setting up the Larson-Davis CAPS Software**.

Enter the Test Documentation

The Documentation window contains four tabs that contain fields for information about the test. Note that the fields marked with an "**" are exported to the test report when using the automatic report generator tool. These fields must be completed exactly as you wish to have the text appear in the report.

This first tab is Test Information. Complete this sheet as follows:
**Test Number – Enter the number assigned to this test. The general format for the test number will be YY_NNN_X_Operating Mode_a [i.e. 02_000_1_Idle_a, where the unit number (X) and sequence letter (a) are optional, as needed]. See the Document Control Program for information on how tests are named.
**Date – Click on the clock/calendar icon to enter the current date and time.
**Operator – Enter your name.
Test Name – Enter the NIOSH Project Name into this field.
Test Description - Optional field that can be used to enter information about this specific test.
Comments – Optional field for any additional test notes.

The second tab is Source Information. Complete this sheet as follows:
**Equipment Type – Enter the name and type of device under test
Note : Be sure you enter this text exactly as you wish to have it appear on the report.
Manufacturer – Enter the name of the manufacturer for the DUT
**Serial Number – Enter serial number of DUT (if available)
Year Made – Enter the model year of the DUT (if known)
**Dimensions – Enter the major dimensions of the DUT, in millimeters (i.e. 25 x 40 x 15)
Technical Data – Optional field
Operation Conditions – Enter the operation condition (i.e. Idle, Full Load, cutting, etc.) of the DUT.
Mounting Conditions – Optional. Enter if any special isolation or mounting of the DUT is employed (i.e. On Fixture, mounted on neoprene pad, etc.)

The next tab is labeled Instrumentation. These fields should already be filled out in the default file. See "**Setting up the Larson-Davis CAPS Software**" below for default setup information. Edit only if these defaults are not applicable.

The last tab is labeled Acoustic Environment Information. The top part of the form is for environmental conditions. Measure and record the:
**Temperature
**Relative humidity and;
**Barometric pressure in the appropriate fields.

Note: For more information on making environmental measurements, see Measuring Temperature, Relative Humidity and Barometric Pressure in the in "**Measuring**

Environmental Conditions" of this procedure.

The Test Environment and Acoustical Qualification fields should already be completed in the default test file. See **Setting up the Larson-Davis CAPS Software** for default setup information.

When all four Documentation Forms have been completed, click on Next to proceed.

Verify the Test Configuration Setup

The test configuration parameters should be pre-set in the default test file. See **Setting up the Larson-Davis CAPS Software** for default setup parameters. When these setup parameters have been verified, click on Next to proceed.

Verify Hardware Configuration

The hardware configuration parameters should be pre-set in the default test file. See **Setting up the Larson-Davis CAPS Software** for default setup parameters. When the hardware configuration parameters have been verified, click on Next to proceed.

Verify Environmental Correction Values

The environmental corrections should be pre-set in the default setup file. These values were determined when the chamber was qualified per the requirements of ISO 3744 and are verified when proficiency tests are conducted. See **Setting up the Larson-Davis CAPS Software** for default setup parameters. When the environmental correction values have been verified, click on Next to proceed.

Verify Microphone Setup

The microphone setup parameters should be pre-set in the default setup file. See **Setting up the Larson-Davis CAPS Software** for default setup parameters. When the microphone setup parameters have been verified, click on 'Finish' to proceed.

When the setup forms have been completed, the LDCAPS software will prompt the user as follows:

"The microphones have not been calibrated. Click 'OK' to calibrate them now."

Click 'OK' and proceed to the next section.

Calibrate Measurement System

Setup the Calibration

There are two options for calibrating all microphones in the measurement systems. These are:

Calibrate All – Will calibrate each microphone sequentially, requiring the operator to interact with the software at the completion of calibration of each microphone.

Auto-Calibrate – Polls all microphones sequentially until a calibration signal is located. When a calibration signal is located on a microphone, that microphone is calibrated. Upon successful calibration, the software will issue an audible signal, delay for a short time and then continue polling. This routine is helpful when one must calibrate the measurement system without assistance.

This procedure is written around the “Calibrate All” routine.

The normal setup parameters for microphone calibration should already be entered in the default test file. See **Setting up the Larson-Davis CAPS Software** for default setup parameters.

Calibrate Microphones

Locate the Larson-Davis CAL200 calibrator, in Lab cabinet #1. The lab standard calibration parameters are 114 dB at 1,000 Hz. The small black switch on the right side of the calibrator should be in the up position for the 114 dB calibration signal.

Click on the ‘Calibrate All’ button.

Place the calibrator on microphone 1, press the black button on its’ right side and then click OK to begin the calibration.

When the calibration is complete, the software will prompt the user to move the calibrator to microphone 2 and click OK to begin calibration of the second microphone.

Repeat this process until all microphones have been calibrated.

The resulting Calibrated Sensitivity for each of the microphones is displayed in a tabular formation in the Calibration window. The value displayed is representative of the sensitivity of the microphone/preamp/cable combination and is expressed in dB/volt. The nominal sensitivity of the 2541 microphones on the 900C preamplifiers is 121-122 dB/volt.

A chart showing the nominal sensitivities of the microphones and the allowable range of sensitivities to be accepted during a “normal” calibration is posted on the lab test bench. Calibration sensitivities shall be within the range listed or the calibration of any microphone outside of the range shall be repeated several times. If a microphone cannot be calibrated within the posted range, this shall be noted in the test file.

Check to make sure all calibration corrections are in the allowable range.

Use Check Level to Confirm Calibration (if necessary)

Proper calibration may be checked by placing the calibrator on the microphone in question and clicking the “Check Level” button. The check level window will display 94.0 dB for properly calibrated microphones.

Save the Calibration Sensitivities

Standard NATF procedure requires that the microphone sensitivities used for each project (file number) be saved. This data is utilized for quality assurance analysis and can be a diagnostic tool if the test data from any project is in question.

If you are planning on running multiple tests during the same measurement session, you may import them during the next test. This procedure requires that microphones be calibrated during each measurement session. (If at any time during a measurement session a question arises concerning the validity of the calibration, standard laboratory procedure requires the test operator to re-calibrate.

To export calibration sensitivities, click on Export Corrections. Give the calibration sensitivity file a file name that includes the project number from which the sensitivities were exported concatenated with the characters “_cal” (i.e. 02_001_cal) and then click on Save.

Exit the Calibration Routine

When the calibration of all microphones is complete, click OK to accept the calibration corrections.

The final prompt of this section will be:
“We’re finally ready to run the test. Click ‘OK’ to continue.”
Click on ‘OK’ and proceed to the next section of this procedure.

Ambient Noise Level Measurement (DUT Off Sound Pressure Levels)

Set up for Ambient Noise Level Measurement

Make sure that the DUT is turned off.
Confirm proper HVAC conditions.
Close the door to the chamber.

Start the Ambient Noise Test Routine

The LDCAPS software should be in the Run Tests Window and the Ambient Noise Test selection should be highlighted. Click on “Run Test” to continue.

You should be in the Ambient Noise Test Window. Click on "Read All Locations" to proceed with the measurement of the ambient noise levels in the chamber.

Click on Start to begin the measurement of the ambient noise.

Range the Instrument

If Auto-ranging has been enabled (default operational mode for LDCAPS using this procedure) you will see a window indicating that the instrument is Auto-ranging.

After a few seconds (see auto-range time settings in **Setting up the Larson-Davis CAPS Software**) the Confirm/Modify Range dialog box will appear and will indicate the range the instrument has selected for the measurement. For the typical ambient sound pressure spectrum in the chamber (posted on lab bench), this will be the –10 to70 dB range.

The operator may over-ride the auto-range settings by clicking on the <up arrow> or <down arrow> indicators on the scroll bar beside the range dialog box. At the same time, the operator should observe the display on the 2900B analyzer. The proper range setting will result in the linear (∑ bar on 2900B display) sound pressure level being about 20 dB down from full scale.

Once the proper instrument range has been determined, click on "Accept" to proceed with the measurement of the ambient noise levels.

Measure the Ambient Sound Pressure Levels

A dialog box indicating that the software is "Testing Location N" (where N is the location number) will appear.

You should be able to watch the software toggle the multiplexer as it steps through the measurement of the ambient sound pressure levels present at each of the measurement locations.

Review the Ambient Sound Pressure Level Data

Review the ambient noise level data obtained to insure that reasonable data is present in all bands for each position. Typical ambient noise levels in the chamber are 25 dBA or less. A copy of the typical 1/3-octave band ambient noise levels in the chamber is posted on the test bench and can be used for comparison. Also check to make sure no data is shown in red, indicating that an overload occurred during the measurement. If an overload occurs on any position, re-measure that position.

Use the <up arrow>, <down arrow>, <left arrow> and <right arrow> scroll bar buttons to move around the ambient noise level data table.

If data at any location is questionable, it can be re-measured by placing your cursor on the Location in question and using the “Read Location N” button. This will cause the software to re-measure Position N. You may also use the “Read from Location N” button to re-measure all data from position N through the last measurement position.

Once the data has been confirmed as being valid ambient noise data, click on “Accept” to enter the data.

Activate the DUT

Power up the DUT

If necessary to operate the DUT from a controlled voltage source, include information on the power supply here.

Turn on the power to the DUT.

Measure, Adjust and Record Operating Voltage. Use a calibrated voltmeter to measure the operating voltage of the DUT. Instructions on how to measure this voltage to be inserted here. Read and record the operating voltage on the database form for this test series.

Configure DUT Operating Mode

Configure the DUT to operate in the mode to be tested. For more information on operating modes supported by the NATF, see Appendix 4, Operating Modes.

Source-On Sound Pressure Levels (DUT On)

Start the Source-On Test Routine

The LDCAPS software should be in the Run Tests Window and the Source-On Test selection should be highlighted. Click on “Run Test” to continue.

To start the measurement procedure, click on “Read All Locations”.

Range the Instrument

If Auto-ranging has been enabled (default operational mode for LDCAPS using this procedure) you will see a window indicating that the instrument is Auto-ranging. After a few seconds (see auto-range time settings in **Setting up the Larson-Davis CAPS Software**) the Confirm/Modify Range dialog box will appear and will indicate the range the instrument has selected for the measurement. The operator may over-ride the auto-range settings by clicking on the <up arrow> or <down arrow> indicators on the scroll bar beside the range box. At the same time, the operator should observe the display on the 2900B analyzer. The proper range setting will result in the linear (∑ bar on 2900B display) sound pressure level being about 20 dB down from full scale.

Once the proper instrument range has been determined, click on “Accept” to proceed with the measurement of the ambient noise levels.

Measure Source-On Sound Pressure Levels

A dialog box indicating that the software is “Testing Location N” (where N is the location number) will appear.

You should be able to watch the software toggle the multiplexer as it steps through the measurement of the source-on sound pressure levels present at each of the measurement locations.

Review the Source-On Sound Pressure Level Data

Review the source-on sound pressure level data obtained to insure that reasonable data is present in all bands for each position. Use the <up arrow>, <down arrow>, <left arrow> and <right arrow> scroll bar buttons to move around the source-on SPL data table.

Check to make sure there is non-zero data in all cells of the worksheet and that no cell contains unreasonably large values. Cells shown in red are a result of an instrument overload during the measurement and should be re-measured. If data at any location is questionable, it can be re-measured by placing your cursor on the microphone in question and using the “Read Location N” button. This will cause the software to re-measure Position N. You may also use the “Read from Location N” button to re-measure all data from position N through the last position.

Once the data has been confirmed as being valid source-on sound pressure level data, click on “Accept” to enter the data.

When the program returns you to the Run Tests window, click on Done.

Save Test Results

The LDCAPS software program will prompt the operator as follows:
“Save Test Data?”
Click on “Yes”.
The Save CAPS Test File box will appear. Enter a test name in accordance with the following format (see also Document Control Program):
YY_NNN_Operating Mode_a
where :
YY = year test was conducted

NNN = sequential test number
Operating Mode = mode device was operating in during test
a = optional character for multiple tests in same operating mode

The file should be saved in the directory named
Enter Directory name here

Click on Save.

Export Test Results

The program will then prompt the operator as follows:
"Would you like to Export the Test Results?"
Click on "Yes" to export the test data into Excel for further analysis, to create an entry for the Acoustics Lab database and/or to prepare the data for the test report.

An export dialog box will appear, providing the operator to give the data file a name. Give the file the same name used to save the sound power test (see step 7.5). It is not necessary to give the file an extension, as a .CSV (comma separated variable) extension is added by default.

Click on OK and the program will launch Excel and import the test results into a spreadsheet.

Save the Excel File

Click on File, Save As.

The name you used to export the data should be displayed in the File name field.

The Save in directory name should be set to C:\NIOSHUC\DataFile. (see step 7.5 for details) If not, redirect this field.

Click on the arrow beside the Save as type field and change the file type to Microsoft Excel workbook. Then, click on Save. Before proceeding in Excel, you should return to the LDCAPS program for a detailed review of the data. Move your cursor to the bottom of the screen to display the Windows95 taskbar. Click on the CAPS application.

The prompt should indicate that "The Automated test process has finished." Click on "OK".

The test data and calculated sound power will be displayed in a spreadsheet format. This data can be reviewed, but not edited. Individual microphones may be re-measured if needed.

Check Data Flags

Check Additional Microphone Positions Needed Flag

You should still be in the LDCAPS program and the test results should be displayed in a spreadsheet format.

Drag the scroll bar on the right side of the screen down until the sound power test results are displayed.

Test bands in which a "Yes" appears in the "Add'l Mics Needed" column have not satisfied the requirements of ISO 3744, section 6.6.3.i.a. This section requires that the difference between the highest sound pressure level and the lowest sound pressure level in each band not exceed the number of microphone positions.

Note : It is unusual for the Add' Mics Needed flag to be set when testing a normal DUT. Be sure this flag is not set because a "0" or other erroneous value is included in the test data.

If additional microphone positions are required the following procedure can be used to satisfy this requirement:

Complete the analysis of the first sound power test in accordance with this procedure
Rotate the DUT 180 degrees.
Re-test the DUT in the 180-degree position and analyze the data in accordance with this procedure.
Average the two sound power results on an energy average basis.

A template file for combining and averaging two sound power tests can be found in the C:\NIOSHUC\Template directory and is named comb_pow_test.xlc.

Determine Bands with Ambient Noise Interference

Test bands in which an "*" appears in the column labeled "Surface Average Ambient Flag" are bands where the Source On sound pressure levels did not exceed the ambient sound pressure levels by at least 6 dB.

Procedures in this area may not be very significant in the NATF, as most devices are expected to generate sufficient sound energy to insure signal to noise ratio.

Analyze Data and Enter Test in Database

Open the Data Analysis Workbook

The Excel file analydata.xlc located in C:\NIOSHUC\analysis directory is used to create a tabular and graphical summary of the test results and formats the data to be entered into the database.

To open the analysis workbook in Excel, click on File, Open. Move to the C:\NIOSHUC\analysis directory and highlight the analysis template file – to be determined. Click on Open.

The data file you want to analyze should already be open in Excel. If not, open it. If it is open, click on Window and the click on the data file.

Import the Test Data

In the exported LDCAPS test data file, highlight cells A1 through AC183. Click on Edit, Copy.

Move to the analysis template file. Click on Window and click on the file.

Click on the tab labeled LDCAPS data and put your cursor in cell A1.

Click on Edit, Paste to place a copy of the test data in the analysis worksheet.

Review the Test Results

The worksheet tab labeled Report Output has been formatted to create a tabular listing and graphical presentation of the test results. Review this worksheet before entering the test results in the database.

Two other analysis tools have been provided for generating formal test reports and declaration reports. These can be found in the C:\NIOSHUC\analysis directory and are called gen_testrep.xlc and gen_declrep.xlc. Detailed information on these analysis routines can be found later in this procedure.

Save the Test Results in the Database

To save the test result in the Database:
List database procedures here

Move on to next test or Proceed to Generate Test Report

This completes the data acquisition, analysis and documentation for the test. You may proceed with another test according to this procedure or move on to the next section to generate an accredited test report.

Generate a Formal Test Report (if required)

Overview of Automated Accredited Report Process

The accredited report procedure utilizes a standard report template in Word that is OLE (Object Linking and Embedding) linked to the Excel analysis template file *Filename*. The process works by directing a series of links in the Excel template file to the exported CAPS test data files for each mode of system operation. Once the linked data is imported into the Excel worksheet template, a Word document, with links to the Excel template file is opened and the links are updated. This causes the data in the Excel template file to be passed to the Word document, generating a test report that needs only minor editing to be a complete report.

It is important to note that the Word report template file is linked directly to the Excel template file and that the Excel file needs to be open and loaded with the appropriate test data when the Word links are updated – to be determined.

Engineering Grade versus Accredited Tests

The primary difference between the NVLAP Accredited and In-House, Engineering Grade procedures using the LDCAPS system is the reporting requirements.

The NVLAP Accredited procedure results in a formal test report that is in full compliance with the reporting requirements of ISO3744. This report is generated using the Excel and Word tools developed to automatically generate formal reports in accordance with the laboratory's accredited report template.

The In-House, Engineering Grade procedure generates a report directly from the Excel export template worksheet that provides a data table, graph and summary specimen description. The completed database entry form for the test specimen provides the sample documentation for this report.

Since both the Accredited and Engineering Grade methods rely on the same test procedure and data analysis, test data obtained and reported as an Engineering Grade report may later be used to prepare an accredited report, provided all specimen documentation is properly recorded in the file.

Retrieve the Accredited Report Generation Template
Start Excel by clicking on the Excel icon on the toolbar.

Open the analysis template file by clicking on File, Open. Move to the C:\NIOSHUC\analysis directory and highlight the file analy_data.xlc. Click on Open.

A dialog box informing the operator that the analysis file contains links to information in other workbooks will appear. Click on "No" to tell the analysis workbook not to update the links.

Update the Links to the Data Files

What will occur in this step is that you will link the Excel report template file to test result files. This will create an Excel spreadsheet with tables and graphs that are properly formatted for a test report. It will also extract documentation on the test specimen to be passed to a report. This Excel spreadsheet will then be linked to a Word document that will create a test report.

To import the data into the Excel report template file, perform the following steps:
Click on Edit, Links.
Highlight the entry for Unit 1_Mode1 and then click on Change Source.
If necessary, change the "Look in" box to the C:\NIOSHUC.
Highlight the name of the file that contains the test data for the Mode 1 test and then click OK.
Highlight the entry for Unit 1_Mode 2 and then click on Change Source.
Highlight the name of the file that contains the test data for the Mode 2 test and then click OK.
Highlight the entry for Unit 1_Mode 3 and then click on Change Source
Highlight the name of the file that contains the test data for the Mode 3 test and then click OK.

When all three links have been updated, click OK to exit the Links window.

Review Report Data Tables and Graphs

The worksheet tabs labeled Mode1, Mode 2 and Mode 3 contain the tabular listing and graphical presentation of the test data that will appear the formal test report. Review these sheets to make sure the proper data has been imported and that the output looks acceptable.

Review Report Information and Enter Your Name

The worksheet tab labeled Report Data contains links to the information that will be exported into the test report. Review these fields to be sure that correct information has been imported into these fields.

On the right side of the screen is a user-input field for the name of the person generating the report. Enter your name in this field.

Retrieve the Report Template File

Start Microsoft Word by clicking on the Word icon on the toolbar.
Open the report template file by clicking on File, Open. Change the "Look in" field to C:\NIOSHUC.

Highlight the file_temp.doc and Click OK

Update the Links in Report Template File

The report template contains links to the Excel file, C:\NIOSHUC\Temp_, which should now be open and updated with the test data from the test you wish to report on. These links must be manually updated as follows:
Click on Edit, Links

Highlight the top link and then scroll down to the bottom link
Hold the Shift key and click on the bottom link. All links should be highlighted.
Click on Update Now

All automatic report generation links will be updated. You should be able to confirm this (without exiting this links window) by moving the links window out of the way and checking the test number and sample name fields on the report cover page.

Break the Test Report Links

In order to keep the test report file from updating the links to the template Excel file, the links need to be broken. Use the following steps to break the links:
Highlight the top link in the links list (you should still be in the links window)
Move down to the bottom of the list using the <down arrow> on the scroll bar.
While holding down the <Shift> key, click on the bottom link. This should highlight all links.
Click on Break Links and then Click on "Yes"

Copy and Paste Tabular/Graphical Test Data

The three tabular/graphical output worksheets created by the Excel analysis template must be manually cut and paste into the Word test report. This is accomplished using the following steps:

Move to Excel by clicking on its' icon on the taskbar.
Click on the Mode 1 Report tab.
The appropriate cells should already be highlighted. Click on Edit, Copy.
Move to Word by clicking on its' icon on the taskbar. Move to the prompt in the Word report template that says "Paste Mode 1 Test Result Table and Graph Here". Paint this text and delete it. Click on Edit, Paste Special. Highlight "Picture", turn the "Float over text" option Off and then click OK.
Repeat this process for the Mode 2 and Mode 3 test results.

Enter Device Under Test Information

The only portion of the test report process that is not automatically generated using the Excel links is the system configuration information contained on Page 2 in the section titled DeviceUnder Test. This information must be manually entered using the information provided by the client on the Specimen Check-In Sheet. Complete this section with the appropriate information.

If several identical units are tested and reported on (i.e. for statistical analysis purposes), it may be helpful to simply cut and paste this information from the previous test report.

Review the Test Report

Perform a detailed review of the test report text, results tables and graphs and header and footer text. The report generator tools have been designed to generate the standard report format but may need to be edited for special situations.

Print the Test Report

Once the report has been reviewed and edited, it may be printed by clicking on the printer icon on the Word toolbar.

Standard lab practice is to print # (#) copies of the test report. Additional copies may be printed as required. Original test reports shall bear the original signature of an approved laboratory signatory for this procedure.

Place one copy of the report in the test file and give it a document number on the test file log.

Save the Test Report

Save the test report in the C:\NIOSHUC\DataFile directory using the name of the test series as the file name – to be determined. Click on File, Save. Enter the test number and Click OK.

Setting up the Microphone Array - in accordance with ANSI 12.15

Setting up the Larson-Davis CAPS Software

Sound Power measurements in the NIOSH Acoustic Test Facility are conducted using the Larson-Davis CAPS Automated Sound Power Measurement Program. This program operates the Larson-Davis 2900B, Dual Channel, Real-Time Analyzer and the Larson-Davis 2226, Microphone Multiplexer. The program guides the user through the test procedure, gathers and analyzes the data.

Note that it is necessary to connect both output channels of the 2226 multiplexer to both input channels of the 2900B. Although the CAPS software operates the 2900B analyzer in a single channel mode, failure to connect both channels will result in data errors on all mics connected to the Channel 2 inputs of each multiplexer.

Typically, the CAPS Sound Power Program will come up configured for the NATF standard test procedure when the file 00_000_x.spp is retrieved. In the event it does not, the following settings will need to be adjusted by the user.

Instrument Connection Communication Parameters

Before a test can be conducted, the CAPS software must connect to the 2900B RTA via the RS232 port. A null modem cable must be connected from the DB9/RS232 connector on the RTA to the RS232 port on the host computer.

The default values that should be displayed in the CAPS Connection window are:

Com Port	Com 1
Baud Rate	19,200
Connect To	Model 2800 or 2900

If the CAPS program fails to connect to the 2900, it may be necessary to check the 2900 communications setup parameters. To access the baud rate on the 2900 analyzer, make the following selections on the 2900 keypad:

SYSTEM
I/O (I)
RS-232 (I)
19200 (P)
EXIT, EXIT

Note : Keys followed with a character in parenthesis after the key name represent soft keys that have the key name shown on the 2900B display. Keys without a character shown in parenthesis after the key name are fixed keys on the 2900B.

Documentation Fields

The default measurement file (00_000_x) has the standard documentation fields already completed. The default entries in these fields are as follows:

Instrumentation

Instrument Name	Larson Davis RTA
Type	2900B
Manufacturer	Larson-Davis
Serial Number	1009
Calibration Date	mm/dd/yy (or date of latest calibration)
Place	Larson-Davis (or place of latest calibration)
Results	Within Manufacturers Tolerances

Windscreen Properties N/A

Test Configuration

Surface Type	Hemispherical
Source Location	Next to 1 Reflecting Plane
Measurement Points	5
Measurement Surface	2.0 meter

Hardware Configuration

Multiplexer Setup	Using MUX at address 0 and 1 should be checked
Number of Microphones	5
Lower Frequency Limit	100 Hz
Upper Frequency Limit	10 kHz

Environmental Correction Values (ISO 3744 K_2)

Refer to Appendix 9, Laboratory Standard Test Parameters, for the latest K_2 values to be utilized.

Microphone Setup

All Location X = Microphone X
Averaging Time = 30 sec
Pause After Read = Off for all locations

Calibrate Microphones Parameters

When the Calibrate Microphones Operation is selected, the following parameters should be set:
Reference Frequency = 1.00 kHz
Reference Level = 114.0 dB
Averaging Time = 3 seconds

Input Range Options

This test procedure is based on the following settings in the Input Range Options

(Click Options, Input Range). The settings in this window should be as follows:

Enable AutoRanging	= Check mark on
AutoRange Before Each Measurement	= Radio button on
Maximum AutoRange Time (secs)	= 5
Confirm Range After AutoRanging	= Check mark on

Measuring Environmental Conditions

- Hemi-anechoic chamber temperature, relative humidity, and barometric pressure measured using a model 7400 Perception II (Davis Instruments,) monitor. This monitor is certified with a NIST traceable calibration.

Operating Modes for Specific Power Tools and Equipment

- In accordance with ANSI 12.15 or other applicable standard. This section will to be developed and maintained as various tool types are acquired and tested.